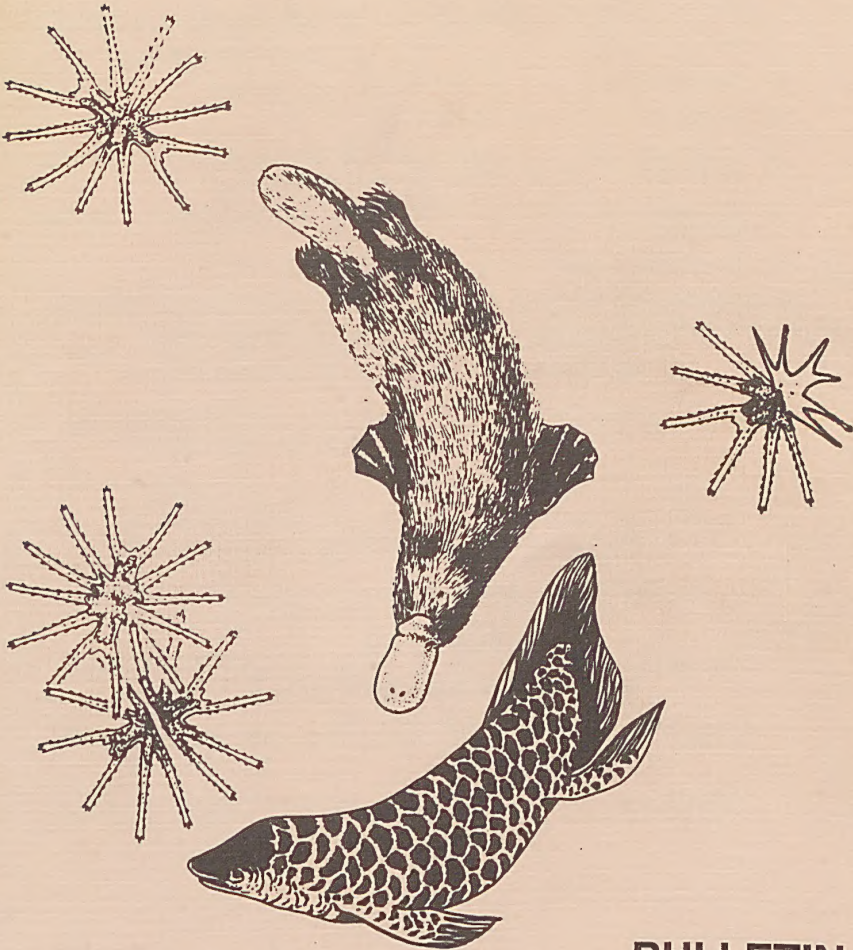


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The *Bulletin* will accept for publication *original contributions*, subject to the following conditions:

1. Papers not directly related to Australia, New Zealand and New Guinea may not be accepted.
2. Taxonomic papers which describe new species will not be accepted unless any "type" material has been deposited at an Australian museum and evidence is presented of its Registration.
3. Manuscripts are to be typed, double-spaced and submitted in duplicate.
4. Photographs will be accepted only in exceptional circumstances.
5. Line drawings, graphs, etc., must be kept to a minimum.
6. All papers will be subject to refereeing.
7. Abbreviated titles of journals cited in "*References*" must conform with the *World List of Scientific Periodicals* abbreviations.
8. 25 reprints will be made available to the author free; additional reprints will be provided at cost.
9. Book Reviews may be accepted for publication.

All communications should be addressed to Dr. S. Bunn, School of Australian Environmental Studies, Griffith University, Nathan, Queensland, 4111.

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THE FAUNA OF MACROPHYTES AND UNVEGETATED SUBSTRATUM IN TWO SOUTHERN VICTORIAN STREAMS

by

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Abstract

Animal communities associated with four species of macrophytes and with unvegetated substratum were investigated at two physically different sites on different Victorian streams. Macrophyte samples contained aquatic (stems and leaves) and benthic (roots) parts. Without correcting for surface area, no differences in the numbers of invertebrates or in taxonomic richness were found between macrophytes and unvegetated substratum at either site. Similar animal communities were found on artificial and living macrophytes suggesting that invertebrate colonization was independent of macrophyte viability and possibly palatability. Classification of animal samples by TWINSpan showed that the animal communities at each site were different and that different communities occurred on macrophytes and unvegetated substratum. The first division was site related but, within sites, the second division indicated that different communities existed between macrophytes and unvegetated substratum. No major trends existed in division of macrophyte samples into further subgroups suggesting that invertebrate community delimitation between the macrophytes was indistinct.

Introduction

Aquatic macrophytes are found in many streams and sometimes form extensive beds which are potentially important habitats for other aquatic biota (Haslam, 1978). Invertebrates can utilise stream macrophytes in several ways: as food (McGaha, 1952; Gower, 1967), as oviposition sites (McGaha, 1952; Soszka, 1975b), as shelter from high current velocities and/or predators (Rosine, 1955; Whitehead, 1935), and as camouflage for predators (Benke, 1976). Reduction of current velocity within macrophyte beds (Westlake, 1961; Edwards, 1969) can result in increased detritus accumulation in this habitat (Minckley, 1963; Ladle and Casey, 1971) which itself may further attract invertebrates (Rabeni and Minshall, 1977; Merritt and Cummins, 1978). Direct consumption of living stream macrophytes is usually minimal (Mecom, 1972; Koslucher and Minshall, 1973; Gray and Ward, 1979; Mackay and Wiggins, 1979; Suren and Lake, in press), but many invertebrates are known to graze epiphytic periphyton (Cattaneo and Kalff, 1978; Best, 1982).

In the present study, invertebrate communities on macrophytes in two southern Victorian streams were compared with those from adjacent unvegetated substratum. To determine whether invertebrates colonise macrophytes primarily to feed on accumulated detritus or periphyton, some plants were coated with latex rubber. After an exposure period to allow periphyton establishment, the fauna was compared with that on adjacent living plants.

Study Sites

The study was conducted in two physically contrasting streams in southern Victoria: Toomuc Creek (TC) near Pakenham (38° 05'S, 145° 29'E) and Lang Lang River (LLR) near Heath Hill (38° 15'S, 145° 42'E). The Toomuc Creek site was approximately 5 m wide and the depth ranged from 90 cm in summer to 150 cm in winter. The substratum was fairly homogeneous and consisted of sand and small gravel particles of approximately 5 mm maximum diameter. Allochthonous material was patchily distributed and included decaying pine needles, large debris and log jams. Riparian vegetation comprised *Pinus sylvestris*, *Leptospermum* sp., *Eucalyptus* spp. and *Callistemon* sp., and grasses (mostly *Paspalum* spp. and *Poa* spp.) which hung into the water from the adjacent steep banks. Dominant macrophyte species at TC were *Ottelia ovalifolia* (Hydrocharitaceae) and *Triglochin procera* (Juncaginaceae), which grew individually in unshaded areas, and *Potamogeton ochreatus* (Potamogetonaceae) which formed a small monospecific bed (3 m x 1 m).

The Lang Lang River site (LLR) was located in a large sandstone gorge vegetated with *Salix babylonica* and *Eucalyptus* spp.. Dense growths of mixed grasses formed the bankside vegetation. The section of stream studied (average width 10 m) consisted of a deep (2 m) pool succeeded by a 50 m fast-water section (depth 50 cm), a 5 m shallow riffle and 50 m of fast water leading to a series of rapids. The substratum consisted of large boulders (up to 30 cm) in fast water and small gravels and sand in slower flowing areas. Most of the macrophytes (*Potamogeton ochreatus*, *Elodea canadensis* (Hydrocharitaceae) and *Typha angustifolia* (Typhaceae)) formed discrete monospecific stands, although isolated plants of *Triglochin procera* grew in fast-water reaches.

Methods

Faunal Sampling

To sample invertebrates associated with macrophytes a hand-operated suction sampler (Boulton, 1985) was used to remove all material from within a sampling box (area = 0.552 m², height = 50 cm). The box was lowered carefully over a plant which was held upright. Whenever water levels exceeded box height, a 300 µm-mesh "glove" was fitted over the box's top prior to sampling to prevent loss or immigration of animals. Plants were uprooted, rocks or boulders within the box removed after cleaning, and the underlying substratum to 10 cm was stirred vigorously. The resulting slurry was pumped into a collecting net (mesh size 300 µm) until the outlet water ran clear. In May 1985, four replicate samples of *T. procera*, *O. ovalifolia*, *P. ochreatus* and bare substratum were taken at TC, whereas five replicates of *T. procera*, *P. ochreatus*, *E. canadensis* and bare substratum were taken at LLR. All samples were preserved in the field with 5% formalin, and later elutriated onto nested sieves (mesh sizes 2.5 mm, 1.0 mm, 0.5 mm). Material collected by the 2.5 mm sieve was sorted by eye whereas the contents of the other sieves were counted and identified under a binocular microscope (5-25x magnification).

Inedible Plants

To prevent the invertebrates which colonized the macrophytes from feeding directly on plant tissues, four *T. procera* plants from TC were coated with a thin layer of latex rubber, rendering them inedible but maintaining their natural morphology and flexibility. Inedible plants were tagged, weighed down with

stainless steel weights and returned to their original locations for 1 month, when they were sampled concurrently with other plants in May 1985.

Periphytic colonization of the inedible plants was assessed by means of scanning electron microscopy. Segments of leaf (before and after colonization) were fixed in 2% glutaraldehyde in phosphate buffer (pH 7.5) and dehydrated in a graded alcohol series. After freeze-drying they were mounted on aluminium stubs, coated with platinum and viewed with an ISI-600 scanning electron microscope.

Surface Area Calculations

The surface areas of morphologically simple plants (*T. procera* and *O. ovalifolia*) were determined directly with an electronic planimeter (Kontron Image Analysis System) whereas those of morphologically complex plants (*P. ochreatus* and *E. canadensis*) were measured by the surfactant method of Harrod and Hall (1962). Leaves of known area were immersed in acetone, air dried, weighed, re-immersed in 2% solution of "Teepol" surfactant and reweighed. A calibration curve of the weight of surfactant solution coating the plant versus its known surface area was constructed, and unknown surface areas of plants sampled subsequently were determined from this curve after coating them with "Teepol".

Statistical Analysis

Species richness, total numbers of individuals, and population densities of selected taxa were calculated for each substratum (individual macrophytes and unvegetated bed) at each site. Analyses were conducted on the numbers of individual taxa (after correction for surface area), and on species richness data (without correcting for surface area). Invertebrate abundance data were analysed both ways.

Where heterogeneous variances were detected using the $F_{\max}$ test, data were $\log_{10}(x+1)$ transformed prior to conducting analyses of variance (ANOVA). If transformed data still did not pass the $F_{\max}$ test, the Kruskal-Wallis test was applied (Zar, 1974). Where appropriate, *a posteriori* comparisons were made amongst treatments using either the Student-Newman-Keuls test (SNK) (parametric data) or the non-parametric Multiple Range Comparison test (MRC) (Zar, 1974).

Data from both sites were analysed using the classification procedure of Two-Way Indicator Species Analysis (TWINSpan: Hill, 1979). The classification was performed with invertebrate abundance data and was conducted on combined data from both sites. TWINSpan analyses were performed with and without surface area corrections to ascertain whether surface area affects classification.

Results

The fauna at both sites was dominated by insect larvae, oligochaetes, and molluscs; crustaceans were also abundant at LLR (Table 1). Although a richer fauna existed at LLR than TC (48 taxa compared to 32), there was no significant difference in the number of taxa per sample at the two sites ($\bar{x}=20$ taxa per sample at TC and 28 at LLR, $t=1.29$, $p>0.05$).

No significant differences in the total abundances of animals were found between macrophytes and unvegetated substrata at either site (TC, $H=7.414$; LLR, $H=2.177$; $p>0.05$) nor were there differences when calculated on an abundance per unit area basis at TC ($H=6.278$, $p>0.05$). At LLR, however, significantly higher invertebrate densities were found on unvegetated substrata and *Potamogeton* (7390 and 4780 individuals/m² respectively) than on *Elodea* and *Triglochin* (3440 and 2220 individuals/m²) ($H=9.309$, $p<0.05$) (Fig. 1).

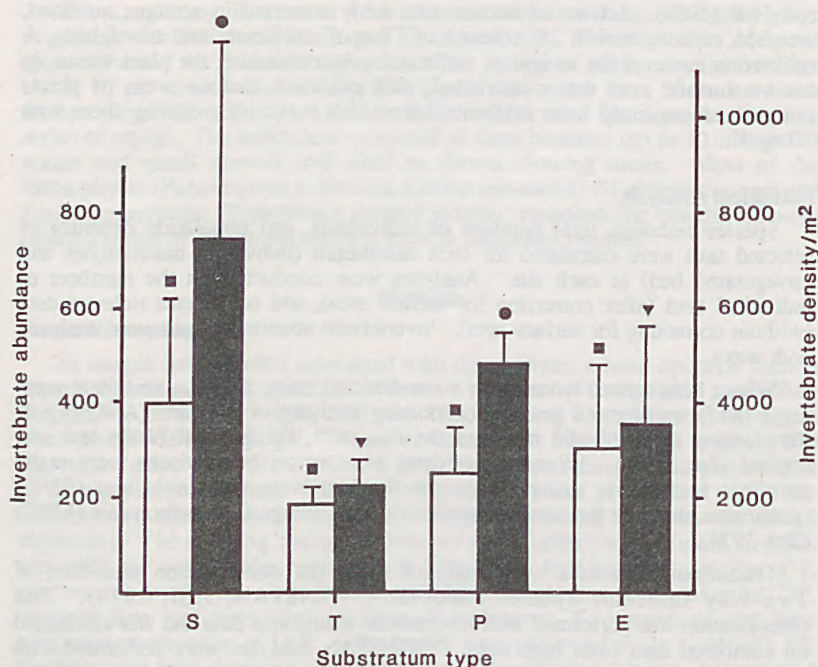


Figure 1: Abundances of invertebrates at Lang Lang River ($\bar{x}\pm 1SD$, $n=5$). Open bars indicate abundances uncorrected for surface area, closed bars indicate abundances per unit area (density). S=bare substratum, P=*Potamogeton ochreatus*, T=*Triglochin procera*, E=*Elodea canadensis*. The symbols over the bars signify that their means are not significantly different from other bars with the same symbol ($P>0.05$, $n=5$).

Numerically dominant taxa were identified at each site and analysed for habitat preferences. Of the 14 taxa selected at TC, only three were present in significantly different densities in particular habitats (Table 1). Densities of conoesucid larvae (Trichoptera) were higher on *Otella* ($\bar{x}=150$ individuals/m²)

than in other habitats (ranges from $\bar{x}=18$ to $\bar{x}=75/\text{m}^2$, $H=9.51$, $p<0.05$). Densities of *Candqnocypris* sp. (Ostracoda) were higher in unvegetated substrata ($\bar{x}=380/\text{m}^2$) than on macrophytes (ranges from $\bar{x}=140$ to $\bar{x}=150/\text{m}^2$, $H=9.24$, $p<0.05$), whereas the bivalve *Pisidium casertanum* (Sphaeriidae) was more abundant on *Triglochin* ($\bar{x}=3200$ individuals/ m^2) than in other habitats (ranges from $\bar{x}=330/\text{m}^2$ to $\bar{x}=2770/\text{m}^2$) ($H=10.64$, $p<0.05$). Larval odonatan (Chlorolestidae, Coenagrionidae and Gomphidae) were absent from unvegetated substratum but were present on all macrophytes.

Of the 17 dominant taxa at LLR, seven showed significant habitat preferences when surface area was considered (Table 1). Densities of the larval trichopterans *Atriplectides* sp. (Atriplectidae) and *Triplectides ciuskus* (Leptoceridae), the coleopteran larvae *Austrolimnius* sp. G and *Austrolimnius* sp. O (Elmidae), and the bivalve *Pisidium casertanum* were significantly higher in unvegetated substratum than on macrophytes ($H=10.09$, 13.06 , 12.88 , 12.18 , and 8.67 respectively, $p<0.01$).

The density of conoesucid larvae was highest on unvegetated streambed and on *Triglochin* ($\bar{x}=230$ and 250 individuals/ m^2 respectively), infrequent on *Potamogeton* ($\bar{x}=25/\text{m}^2$) and absent from *Elodea* ($H=13.37$, $p<0.05$). *Potamogeton* was the least favoured habitat of *Pygmanisus* sp. (Planorbidae) ($H=9.52$, $p<0.05$) which was present in similar densities in all other habitats.

Scanning electron micrographs of latex-coated plants before and after immersion clearly showed that periphyton had established in one month. It consisted predominantly of diatoms (species of *Synedra*, *Cocconeis* and *Gomphonema*) and filamentous green algae (*Ulothrix* sp.).

TWINSPAN Analysis

Different classifications of animal communities on macrophytes and unvegetated substratum from TC and LLR were obtained when surface area was and was not considered. When surface area was not considered, the first division was clearly related to site differences, except for one LLR *Potamogeton* sample which grouped with the TC samples (Fig. 2). The indicator species for LLR was the shrimp *Paratya australiensis*, which was absent from all TC samples and from LLRP3. The TC samples then split into vegetated and non-vegetated communities at division 2, with *Dugesia*, Gomphidae, and Conoesucidae being indicators of vegetated sites (Fig. 2). The vegetated communities then separated into latex-coated plants and normal macrophytes, with three of the four *Triglochin* samples grouping together. Although the *Potamogeton* sample from LLR, i.e. LLRP3, remained with the "*Triglochin*" subgroup until division 4, the absence of Gomphidae from this sample caused it to split from the TC samples.

Unvegetated samples did not immediately separate from macrophyte samples at LLR, and were grouped with *Triglochin* and two *Elodea* samples at division 2 (Fig. 2). The other subgroup formed at this division consisted largely of *Potamogeton* and *Elodea* samples. Four of the five unvegetated samples, however, separated from the *Triglochin/Elodea* complex at division 3, with *Austrolimnius* sp.O as the indicator for bare substratum. This agreed with observations on absolute abundance data where numbers of this taxon were higher on bare substratum than on macrophytes (Table 1). The macrophyte faunal samples remained grouped together until division 4, with the two remaining *Elodea* samples being grouped together due to lower abundance of Conoesucidae, and the last unvegetated sample separated from the remaining

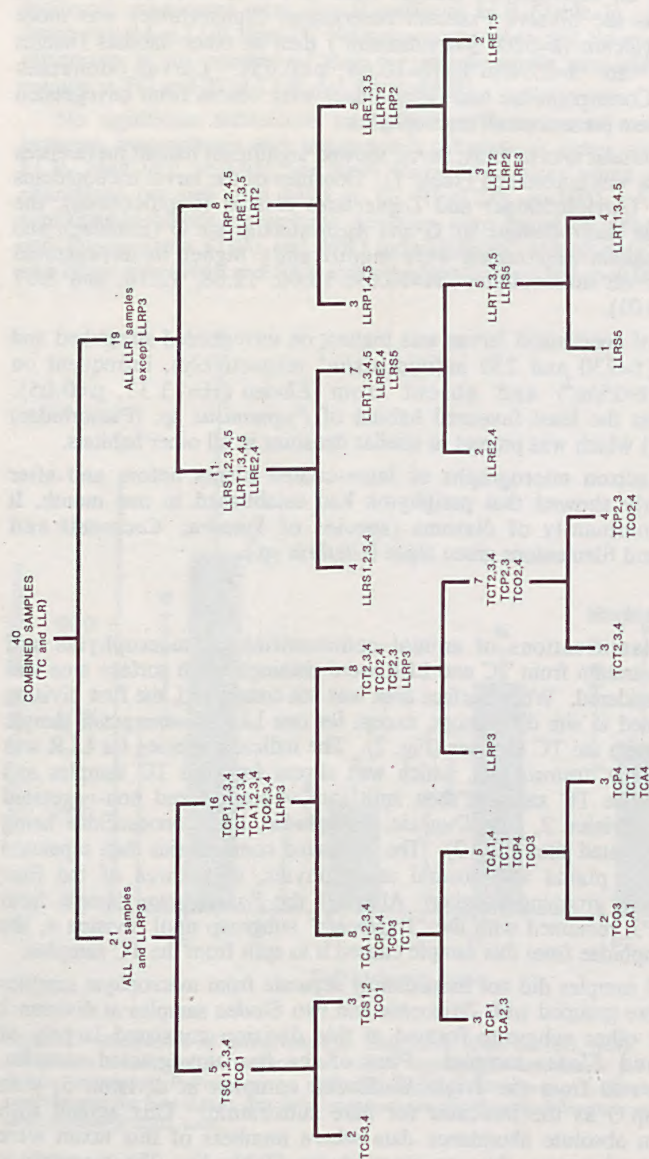


Figure 2: TWINSpan classification performed on raw abundance data of combined samples from TC and LLR showing divisions of samples into smaller subgroups of similar invertebrate communities. The number of samples included in each subgroup is indicated by the uppermost number below which are listed the sample locations. O = *Otella ovalifolia*, A = latex-coated *Triglochita*, other symbols as per Fig. 1.

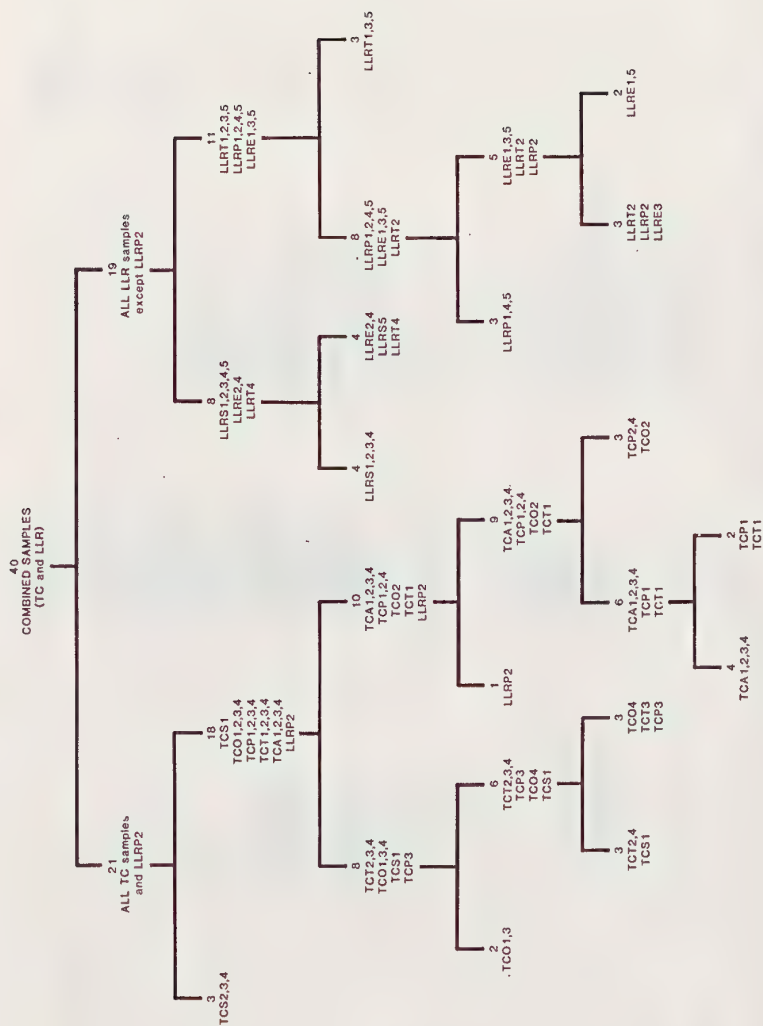


Figure 3: TWINSpan classification performed on data corrected for surface area, of combined samples for TC and LLR showing divisions of samples into smaller subgroups of similar invertebrates. Conventions and abbreviations as per Figs 1 and 2.

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[illegible]

Table 1: List of invertebrate taxa found in all macrophyte and benthic substrates sampled at the two study sites. Symbols + = present, # = abundant enough to conduct statistical tests for evidence of habitat preference within each site. Of the taxa selected for further analysis, ** indicates significant differences in distribution between macrophytes and bare substratum ($P < 0.05$), and (***) indicates animals were absent from bare substratum samples. Species notation for Elmidae is from an unpublished key from the National Museum of Victoria.

group of four *Triglochin* samples at division 5. The other macrophyte samples separated at division 2 and appeared to have less similarity between them, although three out of four *Potamogeton* samples remained together at division 3.

When the abundance data were corrected for surface area differences, TWINSpan produced a slightly different classification of samples (Fig. 3). Division 1 was still essentially on the basis of site. Division 2 of the TC samples also separated out vegetated from most non-vegetated samples, with Conoesucidae indicating the former and *Austrolimnius* sp.G the latter. Division 3 separated latex-coated plants from intact plants, classified three *Potamogeton* samples with the inedible plants, and made *Triglochin* and *Ottelia* the dominant samples in the other subgroup. Of the three indicator species for this division, the bivalve *Pisidium* was also significantly more abundant on samples in this latter group and occurred infrequently on both the latex-coated plants and *Potamogeton* samples. Unlike the previous TWINSpan analysis, six divisions were performed here, and inedible latex-coated plants, not *Triglochin*, remained clustered throughout classification.

Separation of macrophytes from bare substratum was better defined at LLR with surface area corrections than without, with *Paratya australiensis* indicating vegetated samples and *Pygmanisus* identifying bare substratum. The macrophytes were then divided into *Triglochin* samples, indicated by *Tasmanocoenis*, and a *Potamogeton/Elodea* complex subgroup, which was further divided at divisions 4 and 5. (Fig. 3)

Discussion

In contrast to most previous studies of macrophyte fauna (e.g. Soszka, 1975a, 1975b; Rooke, 1986; Pardue and Webb, 1985; McCauley, 1975; Minto, 1977; Stark, 1980), which considered only the "phytomacrofauna" associated with the above-sediment plant, the present study examined invertebrates associated with both aquatic (stem and leaf) and sediment (root) environments.

Comparisons with previous studies are difficult but conflicting trends between the fauna of macrophytes and of bare substratum are discernible. Some macrophytes appear to support fewer (e.g. Rooke, 1984) and others more (e.g. Soszka, 1975a, 1975b; Rooke, 1986) invertebrates than unvegetated substrata. Pardue and Webb (1985) found slight seasonal differences in invertebrate abundance between bare substrata and *Myriophyllum spicatum* but, when surface area was taken into account, total invertebrate densities were the same. Because some workers (e.g. Rooke, 1984, 1986) sampled macrophytes and other substrata with different methods, observed density differences may have been due to different sampling efficiencies. In the present study, a suction sampler was used throughout to eliminate this source of bias.

Sampling macrophytes and bare benthic substratum by this technique revealed no differences in abundance or species richness of invertebrates at either site when surface area of macrophytes was not considered. After correcting for surface area, invertebrate densities at TC were similar on all substrata, whereas at LLR unvegetated substrata and *Potamogeton* had higher densities than those found on other macrophytes.

Although macrophytes can alter stream microenvironments (Gregg and Rose, 1982), they appeared to affect only a small proportion of taxa at TC. Of these, only the ostracod *Candonocypris* was affected negatively, perhaps because macrophyte exudates may have repelled these small crustaceans (Pennak, 1973).

The apparent avoidance of the latex-coated *Triglochin* plants by *Pisidium* may have been due to a reduction in available food supply. Natural *Triglochin* has a large, tangled root mass with thick tubers and stolons that ramify over the substratum and thus may trap much more detritus and particulate organic matter than the inedible replicates.

Odonate larvae were found only on macrophytes at TC. Many dragonfly larvae are "sit and wait" predators, and Benke (1976) has suggested that macrophytes provide such animals with suitable camouflage from prey. However, gomphid larvae sit and wait for prey in burrows (Tillyard, 1917) and their apparent restriction to macrophyte samples in the present study may have been because large amounts of detritus were trapped by plants and provided suitable burrowing sites.

Macrophytes have long been thought to attract invertebrates by producing a substratum for periphyton growth (Shelford, 1918; McDermid and Naiman, 1983; Rooke, 1984). Although complex leaf morphology may result in an increase in periphyton density (Gregg and Rose, 1982), and consequently increase invertebrate density (Harrod, 1964; Rooke, 1986), no clear trend was observed in this study between plant form and invertebrate density. *Triglochin* supported more animals at TC than the morphologically complex *Potamogeton*, possibly because of its larger surface area. *Elodea* had the most complex morphology of all macrophytes sampled at LLR yet it supported only intermediate numbers of animals. Although greater leaf dissection may increase the quantities of colonizing periphyton and detritus trapped by *Elodea*, the location of this plant in fast water riffles may result in increased disturbances and leaf movement which may impair invertebrate colonization (Rooke, 1984). *Elodea* was also, the only exotic macrophyte sampled and this may partly explain its low colonization by invertebrates. While some studies have shown no differences between exotic and introduced plants (e.g. Biggs and Malthus, 1982), some exotic macrophytes have been shown to support fewer invertebrates than native plants (e.g. Keast, 1984; Rooke, 1986).

Most invertebrates in this study did not favour particular plants, and colonized latex-coated and natural plants equally. This suggests that invertebrate colonization of macrophytes is independent of plant species. Macrophytes supply an indirect food source via epiphytic periphyton and trapped detritus (Shelford, 1918; Rooke, 1984; Thomas, 1987) and provide shelter to invertebrates from currents (Rosine, 1955); this may explain why artificial plants often support similar communities to real plants (Glime and Clemons, 1972; Smith-Cuffney, 1987; Dudley, 1988; Suren, 1988). The latter studies utilised artificial mimics made up of unwoven rope and plastic (Glime and Clemons, 1972), astroturf (Smith-Cuffney, 1987), plastic aquarium plants (Dudley, 1988) or nylon twine woven into a mesh base (Suren, 1988). However, the use of latex rubber to coat real plants may be a better way to obtain realistic inedible macrophyte mimics.

The results of community classification using TWINSpan showed that the major differences between animal communities was related to site. Thus, samples from the slow-moving and smaller Toomuc Creek were separated from those from the larger, faster-flowing Lang Lang River. With the exception of the surface-area-uncorrected LLR samples, TWINSpan clearly distinguished between the fauna of vegetated and unvegetated areas, and identified communities within these areas that were different.

No clear trend was detected in the division of macrophyte samples into subgroups of similar animal communities, indicating that neither surface area nor macrophyte morphology was important in determining animal communities at this site.

Similarly at LLR, separation of macrophyte samples into subgroups of similar faunal composition, with and without correction for surface area, appeared to be independent of macrophyte surface area or morphology. Instead, current and habitat stability appeared to influence animal communities more than choice of macrophyte. Replicate samples of *Potamogeton* and *Triglochin* tended to remain clustered together indicating a relatively similar community on each macrophyte. *Elodea* samples, however, were split into three smaller subgroups, indicating lower similarity between them.

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**SCLEROPAGES LEICHARDTI GÜNTHER (OSTEOGLOSSIFORMES):
THE CASE OF THE MISSING H.**

by

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Abstract

Ludwig Leichhardt (1811-1848?) collected a new species of osteoglossid from the Mackenzie River, a tributary of the Fitzroy River, Queensland, in January 1845. Günther described the fish as *Scleropages leichardti*. He misspelled Leichhardt's name throughout the description and listed the locality as the Burdekin River, Queensland. The purposes of this paper are to resolve the confusion about the type locality and to remind authors that according to the rules of the International Code of Zoological Nomenclature, *S. leichardti* is the accepted spelling.

Introduction

Friedrich Wilhelm Ludwig Leichhardt (Figure 1) was born in Prussia and attended two German universities. There is no evidence that he received a degree although the press mistakenly granted him the title of 'doctor' (Aurousseau, 1968; Anon., 1977a). Leichhardt fled Germany to evade military service and arrived in Sydney, Australia, on 14 February 1842. He became an enthusiastic explorer. His major accomplishment was leading an expedition from Brisbane to Port Essington at the northern tip of Arnhem Land, Northern Territory, which was reached on 17 December 1845. This adventure lasted 14 months and 17 days and covered 4800 km. This physically exhausting trek was very important to the Australian colonies for it identified large areas of potential settlement and discovered many major rivers. The Leichhardt River, a 480 km permanent stream in northwest Queensland which flows north into the Gulf of Carpentaria, is one of many physical features named after him. Leichhardt's unexpected return to Sydney by boat (it was assumed he had perished *en route* to Port Essington) created a sensation, and he became one of the most famous figures of the day. In April 1848, Leichhardt and companions left southern Queensland on a proposed (4400 km) transcontinental journey to Perth. The fate of the party remains to this day one of the chief mysteries of the Australian bush (Anon., 1977a, 1977b).

Leichhardt was a strange man - a Faustian mystic who believed himself to be one of God's elect and destined for greatness. His critics were revolted by his personal habits such as licking the sugar bowl, devouring food with the savagery of a starving beast, and his propensity for passionately kissing men (Clark, 1973). His bizarre behaviour concerning food is understandable in the context of the privations described in Leichhardt's *Journal*, which is, however, a delightful and sensitive account of his grand adventure (Leichhardt, 1847). His exploits formed the basis for the historical novel *Voss* by Patrick White, who eventually became the first Australian to win the Nobel Prize for Literature in 1973.

On 16 January 1845, at latitude 23° 21' 30", Leichhardt's party secured a specimen of an unknown osteoglossid from the Mackenzie River (Leichhardt, 1847, p.110), a tributary of the Fitzroy River. Leichhardt (p.111-112) wrote:



Fig. 1. Friedrich Wilhelm Ludwig Leichhardt in 1847. From a portrait by William Nicholas. Reproduced from Aourousseau (1968).

'Murphy shot an *Ostioglossum*, a Malacopterygious fish, about three feet long, with very large scales, each scale having a pink spot. We afterwards found this fish in the waters flowing into the Gulf of Carpentaria; both on its eastern and western sides: and, according to the natives of Port Essington, to whom I shewed the dried specimen, it is also found in the permanent water-holes of the Cobourg peninsula.'

Günther (1864) described the new species on the basis of Leichhardt's stuffed 71 cm specimen in the British Museum and a photograph of a 38 cm dry skin from the Australian Museum. However, he stated that the specimen came from the Burdekin River (Günther, 1864). The Burdekin River is approximately 350 km north of the Mackenzie River, and Leichhardt did not discover and name the Burdekin until 2 April 1845 (Leichhardt, 1847, p.199). Leichhardt (1847, p.227) mentioned four species of fishes found in the Burdekin, but none could be an osteoglossid.

There is no record of Leichhardt's specimen in the Australian Museum, and the skin cannot be located (John Paxton, pers. comm., 1987). The British Museum (N.H.) specimen bears registration number 1846.8.27.4, and there is no clue as to why Günther gave the Burdekin River as its locality (Alwyne Wheeler, pers. comm., 1987). Günther's assignment of the fish to the Burdekin was an error, the source of which is unknown. Lake (1978) and Merrick and Schmida (1984) are correct in their assertion that the species under discussion occurs only in the Fitzroy system. Leichhardt did confuse the two species of *Scleropages* by stating that the specimen from the Mackenzie also occurred in the Gulf of Carpentaria drainage basin, but that is another matter.

Günther named the species *Scleropages leichardti* (Figure 2). He consistently misspelled Leichhardt's name throughout the paper by omitting an "h". This misspelling has been repeated by several workers: McCulloch (1929), Ogilby (1954), Munro (1967), Nelson (1969), Lake (1978) and, most recently, Merrick and Schmida (1984) to name just a few.

Other authors (Stead (1906), Whitley (1964), Roughley (1966)) have taken it upon themselves to add the missing "h" without comment. Contributing to the confusion is Weber and De Beaufort's (1913) mistaken use of *leichardti* as the spelling of Günther in their synonymy.



Fig. 2. *Scleropages leichardti*, the saratoga or spotted barramundi, is reported to reach 900 mm and 4 kg. It occurs throughout the Fitzroy River System in eastern Queensland (Merrick and Schmida, 1984). Figure drawn by Lisa R. McElravy.

The Problem

According to Article 32b of the International Code of Zoological Nomenclature (1985), "The original spelling of a name is the 'correct original spelling', to be preserved unaltered unless it is demonstrably incorrect as provided under Section c of this article, in which case it is to be corrected under section d, ..." Section c states that "An original spelling is 'an incorrect original spelling if...' (ii) 'there is in the original publication itself, *without recourse to any external source of information clear evidence of an inadvertent error* , ..." (my emphasis).

Obviously, Günther intended to honour Leichhardt with the patronym. However, he was consistent in his misspelling so that an external source is necessary to detect the error.

Discussion

Confusion about the "h's" has struck even the proud *Encyclopaedia Britannica* 15th edition. On p.129 of volume VI of the *Micropaedia*, one "h" is used to refer the reader to p.416 of volume 2 of the *Macropaedia* where 2 "h's" reside in Leichhardt. In 1863 John Gould described a species of hare-wallaby as *Lagorchestes leichardti*, and he also referred to Leichhardt with one "h" (Gould, 1973). Strahan (1983) cited this marsupial as *Lagorchestes conspicillatus leichardti*. A quick check of the *Australian Gazetteer* revealed six places named Leichardt and 43 entries under Leichhardt, mostly creeks. The historical references cited above (Aurousseau, 1968; Clark, 1973; Anon., 1977a, 1977b) used two "h's" throughout their works as did Leichhardt on the title page of his narrative (Leichhardt, 1847) and in his correspondence.

I brought the spelling error of Günther to the attention of the International Commission on Zoological Nomenclature (ICZN) in order to have *S. leichardti* published in the *Official List of Specific Names in Zoology*. However, I was informed by ICZN Secretary P.K. Tubbs that since Günther's usage was consistent and no biological confusion exists, and since formal application to change the name would cost the ICZN a lot of money and might fail anyway, it is not worth pursuing.

Conclusion

The purpose of this note is to inform scientists and the general reader of natural history that, in light of the ICZN's position, the correct spelling of *Scleropages leichardti* (and the wallaby name) includes only one "h" even though Leichhardt has two "h's." So the sentence, "*Scleropages leichardti* is named after Ludwig Leichhardt" is correct as written. The rules of the ICZN dictate that we must resist the temptation to correct a name on our own. If anyone names a fish after me, I can only hope they use two "r's".

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USE OF EMETICS TO OBTAIN STOMACH CONTENTS OF THE ROCK FLAGTAIL, *KUHLIA RUPESTRIS* (PISCES: KUHLIIDAE), WITH NOTES ON DIET AND FEEDING

by

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Abstract

Rock flagtails dosed with tartar emetic regurgitated 94% of the items in stomachs and 99% of the volume of stomach contents. A stomach pump was comparatively inefficient and difficult to use. Fish survived emetic administration with no apparent ill-effects. Examination of gut contents of a limited number of fish, and tank and field observations, suggest that rock flagtails are catholic feeders, predominantly taking food from the surface.

Introduction

The rock flagtail, or jungle perch, *Kuhlia rupestris*, is one of the few native Australian freshwater fishes which is regularly sought by anglers using lures, and is a highly regarded sportfish. It is widespread, occurring from the south-eastern coast of Africa, through the Indo-Pacific, to the Tuamotu Archipelago in the east (Regan, 1912). In Australia it is confined to the coastal streams of the north-east drainage division, and has been considered endangered (Lake, 1971), due to modifications to these streams. Little has been recorded of its biology. Lake (1971) suggested that it breeds in estuaries, and its widespread distribution indicates marine dispersal of larvae or juveniles. Whitley (1964) reported feeding on 'crustacea etc.' and figs, and Covacevich and Arthur (1980) noted feeding on the tadpoles of the cane toad, *Bufo marinus*.

Detailed study of the feeding habits of this species is essential to an understanding of its biology, and to the design of appropriate conservation measures. However, due to the limited number of fish available for study, and concern over further depletion of remaining populations, killing large numbers of fish for examination of gut contents was considered undesirable. The present study was aimed at finding a suitable method for obtaining gut contents of live rock flagtails. Two methods of obtaining stomach contents from live fish have been described: dosing with emetic, and stomach pumping. Jernejcic (1969) tested three types of emetics, and found tartar emetic (potassium aluminium tartrate) to be the most effective. Giles (1980) reviewed stomach pumping methods and described a syringe sampler which he used successfully on perch, *Perca fluviatilis*.

Methods

Capture and Handling of fish

During December 1981, flagtails were caught in two small coastal streams in the North-east drainage division: Liverpool Creek (145° 56'E 17° 44'S) and Hencamp Creek (146° 22'E 19° 2'S), by angling, using a lure with a trace of 3 kg monofilament nylon attached, by which fish could be lifted from the water. Fish

were handled by grasping the lower jaw, removing the lure, and then placing them in a 25 l container of stream water. Two fish were dosed with emetic (see below) without use of anaesthetic; other fish were anaesthetised in a solution of quinaldine (~1:150,000 dilution). Once the anaesthetised fish turned over, they were subjected either to the stomach pumping technique or to emetic administration, as described below. Following recovery of food items, fish were killed by over-anaesthetisation, and preserved in 10% formalin, with the abdomen slit to allow preservative ingress. A further two fish were obtained by angling and returned alive to the laboratory, where they were held in a 500 l tank. These fish were used to test recovery from emetic administration.

Water temperature was measured in midstream at capture localities with a mercury thermometer.

Stomach Pumping

In the field, the stomach sampler described by Giles (1980) was used on four fish. Water was introduced to the stomach from a syringe attached to a tube 2.0 mm in diameter, and a second syringe was used to withdraw stomach contents mixed with the water, via a tube 15 mm in diameter. The withdrawn contents were then retained on a sieve of 150 μ m mesh and preserved in 10% formalin.

Emetic Administration

Tartar emetic is only slightly soluble; the 1:1 w/v solution reported by Jernejcic (1969) could not be achieved. The saturated solution used was prepared several hours prior to use with excess emetic and was introduced to fishes' stomachs via a 2.0 mm diameter tube attached to a syringe.

Emetic solution (2 ml per fish) was initially administered to two fish (292 and 302 mm fork length) which were not anaesthetised. These fish showed no vomiting response within ten minutes of administration, and were released.

A further ten anaesthetised fish were dosed with emetic. The dose to administer was chosen arbitrarily to be roughly proportional to the size of the fish as follows: <150 mm fork length (F.L.) 0.5 ml (two fish), 150-250 mm F.L. 1 ml (four fish), 250-350 mm F.L. 1.5 ml (four fish). Each fish was held in a container of stream water for fifteen minutes after emetic dosing. Three time intervals were recorded: the time taken for recovery from anaesthetic (as shown by upright swimming), the time taken for first 'coughing' reaction (a repeated flaring of gill-covers accompanied by rapid backward movements of the fish), and the time and duration of projectile vomiting (expulsion of food items).

Food items were recovered on a 150 μ m sieve, and preserved.

Examination of Stomach Contents

Stomach contents were examined under 40x magnification with a binocular microscope. Items were identified, enumerated and an estimate of the volume of items in each dietary category in each stomach was obtained by the method of Hellawell and Abel (1971).

Recovery Tests

Two fish (221 and 321 mm fork length) were held after capture in a 1000 l freshwater tank at $28 \pm 1^\circ \text{C}$. Within 24 h of capture they took a variety of food,

and within a few days would swim rapidly around the tank and splash at the surface when approached. After one week both fish were fed a quantity of large earthworms and were then removed from the tank, anaesthetised, and administered emetic, as described above. After recovery these fish were returned to the tank and subsequent behaviour was observed for five weeks.

Results

Stomach Pumping

The stomach sampler proved difficult to use, requiring two operators and entailing considerable handling of the fish. In addition, a number of tube sizes would be required to accommodate fish of different sizes. Recovery of food items was inefficient (Table 1): of twenty items present, only eleven (55%) were removed, and only 1380 μl (16%) of a total volume of 8840 μl was removed. The largest items not removed were prawns (*Macrobrachium* sp.), which would not fit in the tube used, and also tended to jam by their cephalic spines in the stomach wall. Water temperature during stomach pumping operations was 25.1°C.

Emetic Administration

This method was relatively simple to use and required very little handling of fish. For the ten fish which were anaesthetised prior to administration, recovery from anaesthetic took between 10 and 70 seconds after emetic administration, 'coughing' began between 30 and 270 seconds after dosing, and projectile vomiting began between 60 and 300 seconds after dosing, and continued for up to 240 seconds. For an individual fish, the maximum time taken from dosing until expulsion of items ceased was 405 seconds.

The method was comparatively efficient (Table 2). Of 96 items present only six (6.3%) were not regurgitated, and 9733 μl (98.8%) of the total volume of 9848 μl was regurgitated. The main items remaining in stomachs were small insects and traces of algal material, but, for all fish, where food remained, some of the same type of items had already been regurgitated. Water temperature during emetic administration was 27.5-29.0°C.

Diet and Feeding

A variety of both aquatic and terrestrial food items was obtained from stomachs. For the fourteen flagtails examined, terrestrial arthropods accounted for 67% of the items in stomachs and comprised 29% of the total volume. Prawns (*Macrobrachium* spp.) and figs only accounted for 5% of items, but made up 39% and 27% of the total volume respectively.

Fish which were held in tanks mainly took items from the surface, but also attacked items that sank to the bottom.

Recovery of Fish

The fish which were held in tanks and then dosed with emetic regurgitated nineteen of twenty earthworms fed to them. They did not take food when offered for the first two days after recovery, but exhibited normal feeding behaviour on the third day and appeared unaffected by the treatment, feeding normally for the five weeks of observation.

TABLE 1: Comparison of items recovered from flagtails using a stomach pump, with items not recovered, for four fish from Liverpool Creek, 4/12/81. Occ = number of fish in which item occurred, N = number of items, Vol = estimated volume of items in μ l.

FOOD ITEMS		RECOVERED			RETAINED			TOTALS		
		Occ	N	Vol	Occ	N	Vol	Occ	N	Vol
DECAPODA	<i>Macrobrachium</i> spp	1	2	400	2	2	6400	3	4	6800
INSECTA	Odonata adult	1	1	20	1	1	400	2	2	420
TOTAL AQUATIC		2	3	420	2	3	6800	3	6	7220
INSECTA	Lepidoptera larvae	1	1	30	1	2	60	2	3	90
	Hemiptera				2	4	500	2	4	500
	Hymenoptera	1	1	50	1	2	100	2	3	150
	Diptera	2	3	80				2	3	80
ARACHNIDA	Araneae	1	1	800				1	1	800
TOTAL TERRESTRIAL		3	6	960	2	8	660	3	14	1620
GRAND TOTAL		4	9	1380	3	11	7460	4	20	8840

TABLE 2: Comparison of items regurgitated and retained for flagtails dosed with emetic, for ten fish from Hencamp Creek 18/12/81. Abbreviations as for Table 1. Note: one stomach contained no food.

FOOD ITEMS		REGURGITATED			RETAINED			TOTALS		
		Occ	N	Vol	Occ	N	Vol	Occ	N	Vol
DECAPODA	<i>Macrobrachium</i> spp	2	2	480				2	2	480
INSECTA	Ephemeroptera	2	11	56	2	2	7	2	13	63
	Diptera	2	5	1				2	5	1
	Hemiptera	4	5	153				4	5	153
PISCES	Scale				1	1	1	1	1	1
ALGAE	Chlorophyceae	2		150	1		50	2		200
TOTAL AQUATIC		5	23	840	3	3	58	5	26	898
INSECTA	Orthoptera	1	1	1000				1	1	1000
	Coleoptera	3	9	2105				3	9	2105
	Hymenoptera	3	49	610	2	3	40	3	52	650
ARACHNIDA	Araneae	2	2	105				2	2	105
PLANTS	Figs	1	6	5000				1	6	5000
	Other	5		73	1		17	5		90
TOTAL TERRESTRIAL		6	67	8893	3	3	57	6	70	8950
GRAND TOTAL		9	90	9733	5	6	115	9	96	9848

Discussion

In apparent contrast to the results obtained for flagtails, Giles (1980) found stomach pumping to be highly efficient for perch, *Perca fluviatilis*, (99.1% average recovery). However, the stomachs of these fish contained mainly small food items, such as aquatic insect larvae, and recovery of the smallest items was more efficient. Giles recommended the use of emetics for fish which take large prey, and Jernećić (1969) observed complete regurgitation of fish fed to largemouth bass, *Micropterus salmoides*. Rock flagtails take a variety of foods in a range of sizes; Giles' stomach sampler, effective for individual fish which had eaten small items, proved inefficient overall. Use of tartar emetic was an effective method of obtaining gut contents of rock flagtails. Jernećić (1969) observed that repeated dosing of one largemouth bass over a period of a week did not cause death, consistent with the favourable results for the two flagtails held in tanks in the present study.

Fish which were not anaesthetised did not show the projectile vomiting response, suggesting that anaesthetisation is necessary when using this method.

The range of foods eaten by the limited number of fish in this study shows that the rock flagtail is a catholic feeder. Its upturned mouth and large dorso-lateral eyes are consistent with predominantly diurnal surface-feeding, as is capture with surface lures, but the finding of prawns in gut contents, and tank observations of bottom feeding, show its ability to catch prey at all water depths.

This small study has shown that detailed assessment of the diet of the rock flagtail could be carried out using tartar emetic to obtain stomach contents. Refinement of the technique to optimise anaesthetic exposure and emetic dosage is warranted, as is some consideration of the effects of temperature on response. Recovery from anaesthetic and the time taken to expel items were rapid at the range of temperatures (27.5-29.0°C) encountered in this study.

Tartar emetic may have applicability in studies of the diet of other fishes, particularly where populations are small. However, factors to be considered in comparisons with other species and localities include water temperature and metabolic rate of the species.

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THE FAUNAL ASSEMBLAGE (OR PHOLETEROS) OF SOME FRESHWATER CRAYFISH BURROWS IN SOUTHWEST TASMANIA

by

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Abstract

A survey of pholeteros from six sites in southwest Tasmania confirms the presence of groups such as nematodes, oligochaetes and arthropods in the faunal assemblage. Between six and thirteen aquatic taxa are recorded from each of the sites sampled, representing a total of 34 taxa. Important distributional records are provided for several groups of Crustacea (such as the Syncarida and Amphipoda) and the identification of trichopteran larvae occupying burrows represents a new record for the fauna. It is suggested that trichopteran and helodid species, at least, are exclusive dwellers of the burrow habitat in alpine conditions in southwest Tasmania.

Introduction

The faunal assemblage occupying the burrows of freshwater crayfish was highlighted by Nicholls (1931), who described the syncarid *Microspides calmani* and other crustaceans from muddied waters in excavated holes of crayfish burrows on the west coast of Tasmania.

Since then there has been an increased recognition of the distinctive nature of the fauna found in these burrows. Lake (1977) coined the collective term 'pholeteros' for the fauna, and provided a list of the crustaceans which occurred regularly in the burrows of *Parastacoides tasmanicus* in southwest Tasmania; further lists of the faunal assemblage of burrows in Tasmania have been provided by Richardson and Swain (1978) and Richardson (1986).

Despite this attention, little or no attempt has been made to determine the importance of the crayfish burrow as a habitat to each occupant species, and whether species in the pholeteros occur in other nearby habitats.

As part of a survey of the aquatic fauna of Southwest Tasmania National Park it was envisaged that the pholeteros might harbour groups of animals which might not be collected by other methods in the survey and consequently this habitat was given special attention.

The aims of the study were twofold: first, an attempt was made to list the aquatic elements of the fauna of selected burrows of freshwater crayfish and to discuss any important features of each animal group in the pholeteros. Second, where possible, an attempt was made to compare the faunistic elements with those found in adjacent habitats on the reasoning that such an attempt might highlight groups of animals which occur exclusively in the pholeteros.

Methods

The precise locations of each pholeteros sample collected are given in Table 1.

TABLE 1: Showing the site number, the method used to collect each sample (see text), the sub-species of *Parastacoides tasmanicus* present in each burrow, the date of collection and the precise location of each burrow.

Site	Method Used	Crayfish Species	Date	No. of Burrows	Location
A	A	<i>Pt.inermis</i>	9.2.87	1	Serpentine River, Southwest National Park, 8012:165 635. Sample from burrow at river level, immediately adjacent to first waterfall below dam.
B	C	<i>Pt.insignis</i>	10.2.87	2	Burrows in peaty/sandy soils on quartzite on slope above, and in flood plain of, a small tributary of Giblin River, Southwest National Park. 8011:986 335
C	A	<i>P.t.tasmanicus</i>	10.2.87	5	Buttongrass plain on walking track, immediately south of Crossing River, Southwest National Park 8111:323 270.
D	C	<i>Pt.insignis</i>	10.2.87	2	Buttongrass-sedgeland adjacent to upper reaches of Hardwood River, Southwest National Park, 8012: 110 442.
E	C	<i>Pt.insignis</i>	11.2.87	2	Scotts Peak region, 8111 : 452 346. Taken from burrow in seepage-depression, buttongrass-sedgeland.
F	B	<i>Pt.inermis</i>	12.2.87	2	Lake Fortuna, Arthurs Ranges, Southwest National Park. 8011: 372 248. Burrows in alpine cushion plant community/pea; soils on quartzite in level areas adjacent to lake.

The method of collection of the fauna varied depending upon the nature of the burrows and the quantity of water in the burrow system. For discrete and apparently shallow burrow systems, a syphon was used to suck out the water with its associated fauna, and this water was passed through a 25 μ m sieve (Method A in Table 1; see below). For these burrows, the water refilled in the tunnels after having been drained by the syphon, and it was therefore assumed that the burrows were associated with a water table (type 2 burrows, *sensu* Horwitz and Richardson, 1986).

For larger burrow systems with many burrow openings in soils where the water table was very close to the surface, a spade was used to carefully remove a circular sod of soil surrounding the burrow openings, thereby exposing the burrow water (the water table). In these burrows this represented a substantial reservoir of water which, for practical reasons, could not be sampled adequately following Method A. Thus, the burrow water was filtered through either a Freshwater Biological Association (FBA) net of 2 mm mesh pore size (Method B) or a sieve of 0.5 mm mesh pore size (Method C).

In all cases the sieved material was washed into plastic bags and preserved in approximately 10% formalin before being transported back to the laboratory.

Prior to sorting in the laboratory, each sample was placed in a 125 μm sieve and washed thoroughly with clean fresh water to remove silt. (Thus, the largest mesh pore size used for samples collected using Method A was 125 μm).

All samples were sorted under low magnification ($\times 3$) and all organisms kept in 75% alcohol.

The number of burrows sampled at each site is given in Table 1. Where pholeteros was collected from more than one burrow at one site, each individual sample was preserved and sorted separately. To avoid unnecessary repetition, the data from each burrow were lumped in this report to give a list of the fauna for each site, rather than each burrow at each site.

Results and Discussion

The species found in the burrows of freshwater crayfish, as well as their relative abundances per burrow, at the six sites are listed in Table 2.

For the purposes of this work, taxa which were found and known to have representatives in aquatic habitats were taken to be true components of the pholeteros. An unfortunate side-effect of this definition was that no distinction could be made between species which dwelt exclusively in the burrow water and those that lived either in interstitial spaces or in saturated soil. Whilst a comparison of collecting methodology (Methods A, B and C) has been deliberately avoided here, perhaps future studies might involve these comparisons and might highlight differences in the microhabitat of each species.

The occurrence of each individual group is examined and their previously recorded occurrences in Australian pholeteros is discussed below.

Nematoda and Turbellaria

Nematodes and turbellarians have been recorded previously from the burrows of two species of *Engaeus* (Horwitz *et al.*, 1985) and from 'crayfish' burrows (Richardson, 1986). The former authors suggested that nematodes were likely to be 'true' (aquatic) members of the pholeteros. Both groups of organisms are difficult to identify and thus the determination of rare or abundant species is difficult.

Oligochaeta

Oligochaetes have been recorded from the pholeteros by Horwitz *et al.* (1985) and Richardson (1986). In this study, 10 aquatic species were found. *Phreodrilus proboscidea* is easy to identify and is widespread throughout Tasmania; its detection in the pholeteros represents an extension of its known habitat range (Fulton, pers. comm.). With the exception of taxa such as *P. proboscidea* and *P. magnaseta*, there appears to be a high site specificity for each species. For instance, of a total of 3 species at site D, 2 were only found at that site despite the fact that the same habitat (buttongrass plains) was sampled on at least two other occasions (sites B and C). Oligochaetes were absent from site A.

		Site A	Site B	Site C	Site D	Site E	Site F
Nematoda					x	x	x
Turbellaria (T)					x		
Oligochaeta							
	<i>Phreodrilus proboscidea</i>			x		xx	xx
	<i>Phreodrilus magnaseta</i>		x				x
	Phreodrilidae sp. 1			xx			
	Phreodrilidae sp. 2		xx		x	x	xx
	Indet. sp. 1		xx				
	Indet. sp. 2		xx				
	Indet. sp. 3		xx			x	
	Indet. sp. 4				x		
	Haplotaxidae sp. 1					x	
	?Haplotaxidae sp. 2				xx		
Arachnida							
- Acarina	?Hydrachnellae sp. 1	x					
Crustacea							
- Ostracoda		x	xx				x
- Syncarida	<i>Allanaspides helonomus</i>			x		x	
	<i>Micraspides calmani</i>		xx		xx		
- Amphipoda	<i>Neoniphargus</i> sp. 1	xx	xxx		xxx	xx	xx
	<i>Giniphargus</i> sp. 1		xx		xx		
	<i>Paraleptamphopus</i> sp. 1				xx		
- Isopoda	<i>Heterias ?pusilla</i>	xx	xx	xx	xx	xx	x
	<i>Phreatoicoides</i> sp. 1		xxx				
	<i>Phreatoicoides</i> sp. 2				xxx		
	phreatoicid sp. 3					xxx	
Insecta							
- Plecoptera	<i>Dinotoperla</i> sp.		x				
- Collembola	<i>Rastriopes</i> sp. (T)				x		
- Diptera	Ceratopogonidae sp. 1		x				
	Ceratopogonidae sp. 2						x
	? Syrphidae			xx		x	
	Tipulidae					xx	xx
	Thaumaleidae			x			
	Chironomidae sp. 1	x			x	xx	
	Chironomidae Pupa sp.					x	
	Tanypodinae sp. 1			x			
	Tanypodinae sp. 2			x			
- Trichoptera	Kokiriidae sp. 1						xx
	Indet. Larvae						x
- Coleoptera	Helodidae sp. 1						xx
	NUMBER OF TAXA	6	13	8	10	13	13

Abundance Key

1	x
2-10	xx
10+	xxx

Table 2: list of aquatic (and terrestrial) taxa from crayfish burrow samples taken from six sites in the southwest of Tasmania. See Table 1 for exact location of sites. Crosses indicate relative abundances; (T) = terrestrial taxa; 'Indet.' = indeterminate.

Acarina

The specimen collected at site A could not be identified to species level. One species of water mite was collected by Horwitz *et al.* (1985).

Ostracoda

The ostracods are likely to be either free-living (aquatic) or parasitic on crayfish. They have been described from the pholeteros previously (Horwitz *et al.*, 1985) and may be significant components of the faunal assemblage; the use of large-mesh nets (500 μm) to collect the fauna may have impeded their collection.

Syncarida

Both genera recorded here have been described from the pholeteros on previous occasions (Nicholls, 1931; Swain *et al.*, 1970; Swain *et al.*, 1971; Lake and Newcombe, 1975; Knott, 1975; Lake, 1977; Richardson and Swain, 1978; Richardson, 1986) and they appear to be a common component of the subterranean aquatic fauna. Indeed, it may be that the technique of sampling for pholeteros is precisely the method which is needed for the collection of these animals.

The present study provides new distributional records for both species. There are two interesting features about these distributional records: first, the occurrence of *Allanaspides helonomus* in the Crossing River drainage represents a significant extension of its known distributional range since the genus was known only from the area of the Serpentine Impoundment (formerly Lake Pedder; Swain *et al.*, 1971; Richardson and Swain, 1978). This is particularly important in the light of the listing of *Allanaspides helonomus* as a "vulnerable" species in the Invertebrate Red Data Book (IUCN, 1983). Second, the two species appear to be mutually exclusive in their distribution, as suggested by Swain *et al.* (1971), where *Micraspides calmani* occurs to the west (and perhaps north) of *Allanaspides helonomus*.

Amphipoda

Amphipods are characteristic of the pholeteros in southwest Tasmania (see, for example, Lake and Newcombe, 1975, and Suter and Richardson, 1977) where they may occur in large numbers (200 in one burrow sample from Site D). The taxonomy of freshwater amphipods in Tasmania is poorly documented at present; nevertheless, it was possible to identify three genera ("*Neoniphargus*", *Paraleptamphopus*, and *Giniphargus*) from the collections. The last-named genus has not hitherto been recorded from Tasmania.

Isopoda

The presence of janirid isopods in pholeteros is well known (Lake and Newcombe, 1975; Lake, 1977; Suter and Richardson, 1977; Richardson, 1986). The occurrence of *Heterias ?pusilla* in the pholeteros at each site, and in relatively high numbers, indicates that this habitat is a significant one for this species.

Phreatoicid isopods have also been described as common components of pholeteros (see, for instance, Knott, 1975; Richardson and Swain, 1978); the

latter authors believed that these forms were burrowers (albeit presumably aquatic ones) through loose mud.

Plecoptera

The presence of stone-fly larvae in pholeteros has been recorded by Richardson (1986). The detection of one specimen found in this study might merely be the result of flooding in a nearby creek at the Giblin River site (Site B).

Collembola

The species recorded in this study is known to occur in heath vegetation (Ireson, pers. comm.) and as such it is not considered to be a true component of the pholeteros since it is not aquatic. Since the only aquatic species of Collembola in Tasmania is cosmopolitan but rare (Ireson, pers. comm.), records such as those presented in Horwitz *et al.* (1985) and Richardson (1986) should be examined critically.

Diptera

Dipteran larvae have been described from pholeteros (Horwitz *et al.*, 1985; Richardson, 1986). All species found in the present study might have been either regular occupants of the burrow water or inhabitants of saturated soil. Chironomid larvae were the dominant dipterans found in this study.

Trichoptera

The occurrence of two species of trichopteran larvae in burrows is important in that this group has not been recorded from this habitat before. The more common of the two species (Kokiriidae sp.) occurred in both burrows examined at Site F; the cases were constructed of quartzitic sand grains and had a flattened, conical shape.

Coleoptera

Helodid larvae have been described from pholeteros in the King River valley (Richardson, 1986). Six individuals were found in one of the two burrows excavated at Lake Fortuna; this may, therefore, represent more than just a freak occurrence of the species in a crayfish burrow.

Habitat Comparisons

In order to determine whether species occur exclusively in crayfish burrows, species lists of the pholeteros may be compared with those of other aquatic surveys. It would be best to compare these lists where other sampling has been conducted in the immediate vicinity of the crayfish burrow samples and in discrete habitats or areas. Sampling programs at the alpine Lake Fortuna in the Western Arthur Range conformed to these conditions. As well as collecting pholeteros samples, a wide range of aquatic sampling was conducted, including FBA net samples in small tributaries of the inflow creek, Surber samples in the creek itself, and rock fauna samples and electrofishing in the lake (Chilcott, 1987).

Whilst it is not possible to compare all the species found in the pholeteros samples due to taxonomic difficulties, the trichopteran and coleopteran faunas are sufficiently well known to allow such comparisons. Indeed, neither of the trichopterans which were found in the pholeteros were found in any of the other aquatic habitats at Lake Fortuna, nor at other sites on the Western Arthur Range (c.f. Chilcott, 1987). Thus, the larval forms of both these species may rely upon the burrow habitat.

Similarly, the helodid from a burrow near Lake Fortuna does not correspond to any helodid species found in a nearby creek, nor to any species found elsewhere on the Arthur Range (c.f. Chilcott, 1987). Thus, subject to further investigations, these larvae may also be regarded as belonging exclusively to the burrow fauna.

In the North American study of Jaspers and Avault (1969) a comparison of the burrow fauna with the fauna of nearby surface waters was made and the authors concluded that the burrow fauna was more depauperate than adjacent ponds and ditches, and that oligochaetes dominated burrow fauna whilst aquatic dipteran larvae dominated the other faunal samples. Unfortunately, no record was made of whether species occurred exclusively in either habitat. The dominance of oligochaetes in the pholeteros has been confirmed in this study.

Further Study

The occurrence of species which are, or appear to be, restricted to the pholeteros, has important implications for aquatic faunal surveys. Future examinations of the aquatic fauna of a region should incorporate a survey of the burrow habitat, not only because of the distinctive nature of the fauna, but also because the sampling technique lends itself well to the capture of certain groups of species. The occurrence in the pholeteros, from two sites, of a genus of amphipod which was previously unrecorded from Tasmania, illustrates this.

In addition, questions about the origins of the subterranean fauna are pertinent. It has been suggested (Creaser, 1931; Williams *et al.*, 1974; Lake and Newcombe, 1975) that the animals found in the pholeteros may recolonize nearby water-ways after periods of drought, leading to the conclusion that the crayfish burrow habitat may develop subterranean faunas (Creaser, 1931). From our results, it can be hypothesized that conditions in crayfish burrows are more favourable for animals in the pholeteros (due, for instance, to the availability of food or buffering from temperature extremes) than conditions in open water where surface freezing during winter periods may have been limiting in some areas (e.g., montane regions of Tasmania). If so, it might then be suggested that drought conditions were not the only force facilitating the establishment of subterranean faunas: cold temperatures may also have played a role.

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A NOTE ON THE DIET OF LATE INSTAR NYMPHS OF *EUNOTOPERLA*
KERSHAWI (PLECOPTERA; GRIPOPTERYGIDAE)

by

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Introduction

Most gripterygid stoneflies are considered to be detritivorous herbivores (Sephton and Hynes, 1983; Yule, 1986; Chessman, 1986) with the exception of two species: *Illiesoperla mayi* (Yule, 1988) and *Eunotoperla kershawi* (Sephton and Hynes, 1983). In a study of predation on stream invertebrates by stonefly nymphs the diet of large late-instar nymphs of *E. kershawi* was determined.

Methods

Individuals of *E. kershawi* were collected, by kick sampling, on four separate occasions in June and July 1987 from a site on Whitehouse Creek (37°29'S, 145°49'E) near Marysville, Victoria. The gut contents of 21 nymphs ranging in total body length from 9.9 to 13.9 mm (excluding antennae and cerci) were examined. Appendages and head were removed from each specimen and the entire gut removed, teased out onto a slide and mounted in poly-vinyl-lactophenol.

Results and Discussion

The lengths and well-developed wing pads of the nymphs of *E. kershawi* used in this study indicate that they were late-instar nymphs (viz. Hynes and Hynes, 1975; Sephton and Hynes, 1982). In the gut contents four prey taxa were identified: Chironomidae (which comprised 58% of total animal remains for all specimens), Ephemeroptera (30%), Trichoptera (7%) and Plecoptera (5%) (Table 1). Of the total gut content material, fine organic matter or detritus comprised less than 20% by volume in any of the specimens. No fresh higher plant material (e.g. bryophyte or macrophyte tissue) was observed in any of the specimens (Table 1).

The gut contents of late-instar nymphs of *E. kershawi* indicate that this species is predominantly carnivorous, eating small animals (especially chironomids). The presence of small amounts of detritus in the gut of some specimens may suggest that *E. kershawi* is an omnivore but the small amounts present may have been incidentally consumed with prey.

Sephton and Hynes (1983) classified nymphs of *E. kershawi* as omnivorous and found detritus to be the most important component of the diet. They also recorded ephemeropteran nymphs, plecopteran nymphs, chironomid larvae and diatoms in the gut contents. The gut contents were similar over the size range (1.5-15.5 mm) of the nymphs they examined. Such a size range covers both small early-instar and large late-instar nymphs (Sephton and Hynes, 1982).

TABLE 1: Gut contents of late instar nymphs of *Eunotoperla kershawi*. (FPOM = fine particulate organic matter).

Specimen	length (mm)	Gut Content Taxa	No.of Indivs. observed	Other contents (by volume)
1	11.52	Ephemeroptera	2	<10% FPOM
2	11.04	Hydropsychidae	1	"
3	11.52	Chironomidae	3(?)	-
4	12.48	Ephemeroptera	2	-
5	11.68	Chironomidae	1	-
		Ephemeroptera	1	<1% diatoms
		Plecoptera	1	<5% FPOM
6	11.60	Chironomidae	1	-
		empty	-	-
7	11.36	Ephemeroptera	1	<10% FPOM
8	12.48	Ephemeroptera	1	-
9	11.68	Chironomidae	1	<20% FPOM
		unidentified	1(?)	-
10	12.32	Plecoptera	1	-
11	12.48	Chironomidae	3	<10% FPOM
12	13.12	Ephemeroptera	2	-
13	13.92	Chironomidae	-	-
		Chironomidae	7	<5% FPOM
14	10.88	Ephemeroptera	1	-
15	10.72	Chironomidae	2	<20%FPOM
16	11.20	Chironomidae	1	-
		Trichoptera	1	-
17	12.48	Trichoptera	1	-
18	13.44	Chironomidae	1	<10% FPOM
19	9.92	Chironomidae	1	-
		Ephemeroptera	1	-
20	11.52	empty	-	-
21	11.04	Ephemeroptera	2	-
		Chironomidae	1	<15% FPOM
		Chironomidae	1	-
		unidentified	1(?)	-

The current observation on late-instar nymphs strongly suggest that they are carnivorous. The diet of *E. kershawi* nymphs may change with age and this resembles that of *Illiesoperla mayi*. Yule (1988) found that large late-instar nymphs of *I. mayi* were carnivorous whereas the early-instar small nymphs were detritivores/herbivores.

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A FREEZE-CORER FOR SAMPLING STONY RIVER BEDS

by

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Abstract

The design and operation of a freeze-corer that uses liquid CO₂ as a coolant is described. This device is sufficiently robust to work in consolidated stony river beds. It is capable of extracting cores 30 cm long with wet weights of 2-6 kg after 4 minutes of freezing. The device is suitable for use in studying the vertical distribution of benthic invertebrates and fine sediments (<2 mm grain size) in river beds.

Introduction

A persistent problem in attempts to quantify the density of benthic invertebrates in river beds is the extent of the vertical distribution of the fauna. It is generally agreed that coring provides the best solution to this problem (Pugsley and Hynes, 1983). However, stony river beds consisting of gravel, pebbles and cobbles, i.e. a range of grain sizes of 4-256 mm, cannot easily be cored mechanically. In two recent studies (Pugsley and Hynes, 1983; Bretschko and Klemens, 1986) frozen cores of sediment were used to assess the vertical distribution of the fauna. Such freeze-coring has also been used by sedimentologists (Carling, 1981) to obtain representative samples of river sediments that include the fine fractions (e.g. <2 mm grain size) which are so readily lost by any method requiring digging.

Liquid nitrogen (Pugsley and Hynes, 1983) and liquid CO₂ (carbon dioxide) (Carling, 1981) have been used to freeze such cores. This paper describes the use of liquid CO₂ to take cores in a stony and, in some places, strongly consolidated river bed: the Thomson River, Victoria, near the Thomson dam. Because the terrain in this region is steep and the only access is over rough roads, liquid CO₂ is safer and more convenient to transport as it is stored (under pressure, 5.0 MPa) in cylinders. Liquid nitrogen, on the other hand, is held in vacuum flasks which are fragile and awkward to handle in the rough terrain. Moreover, the slow evaporation of the liquid nitrogen from the flasks is a disadvantage on field trips of more than 1-2 days.

Our equipment is based on that originally designed by Walkotten (1976) and Stocker and Williams (1972) and modified by Carling (1981) and Pugsley and Hynes (1983). Liquid CO₂ is delivered with a probe to a standpipe partly embedded in the riverbed. Nozzles on the probe discharge the liquid CO₂ to the lower part of the standpipe. The large pressure drop to atmospheric pressure of the CO₂ at the nozzles results in a rapid lowering of temperature (to about -78°C) and production of dry ice, which freezes sediment and water to the standpipe. Our intention here is simply to describe the construction and use of a freeze-corer that combines the standpipes of Pugsley and Hynes (1983) with the CO₂ delivery probe of Carling (1981). Detailed biological and sedimentological results will not be given.

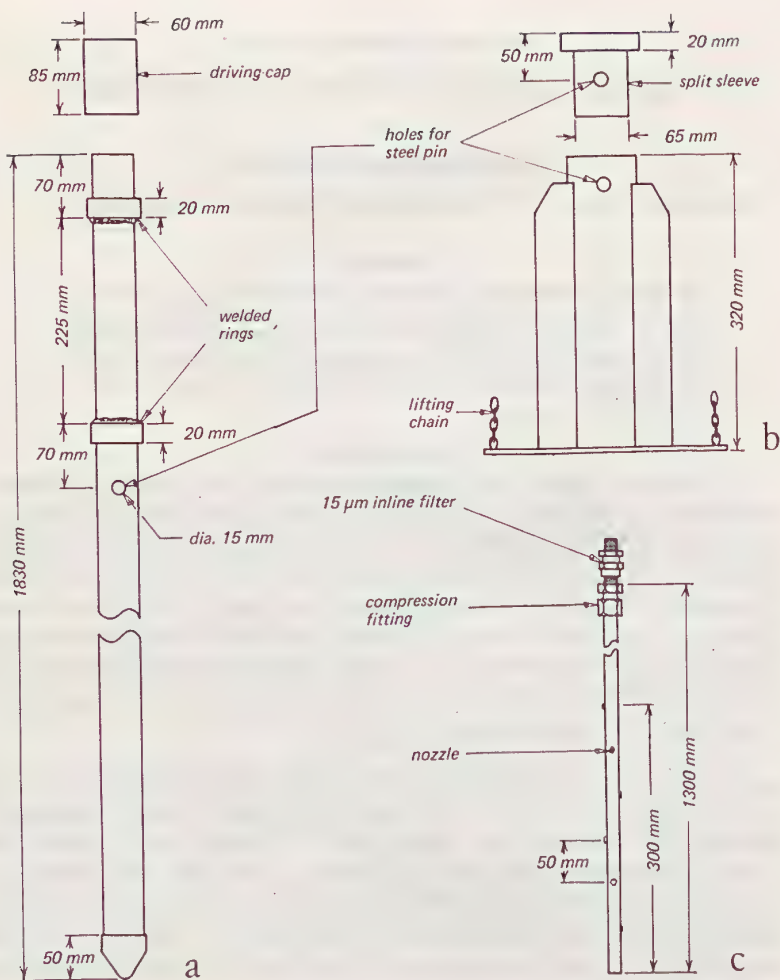


Figure 1: a) The standpipe and the driving cap. b) The lifting assembly. The split sleeves and the steel pin (not shown) are attached to the lifting assembly by chains (not shown). c) The probe.

Design and Construction

The standpipe (Fig. 1) is made from heavy steam pipe (42 mm external diameter; 4 mm walls) and is virtually identical to that used by Pugsley and Hynes (1983). Such a heavy pipe is essential for coring in the consolidated coarse sediments found in the Thomson River; thin-walled copper standpipes as used by Carling (1981) and Walkotten (1976) would distort immediately. The conical steel driving tip is welded onto the lower end of the standpipe as are the steel rings on the upper end. A steel driving cap sits on the uppermost steel ring to prevent burring and distortion of the pipe when it is driven into the river bed. The lower steel ring acts as a lifting point for the lifting assembly (Fig. 1).

The probe (Fig. 1) that delivers the liquid CO₂ is made from steel hydraulic tubing (14 mm external diameter; 3 mm walls) and is similar to the one used by Carling (1981). It is plugged at its lower end with a screw-in plug (Unbraco plug). The nozzles (Fig. 2) are made from brass. Six of these are screwed into the wall of the probe at 50 mm intervals in a spiral around the probe's lower end. The nozzle aperture (180 μ m) is drilled out and is backed by fine copper screening (110 μ m mesh) pushed into place. The threads of the nozzles and the screw-in plug are sealed with a retaining compound (Loctite 680) to prevent leakage of the liquid CO₂. Before assembly all these components should be cleaned of dust and metal particles by flushing with acetone.

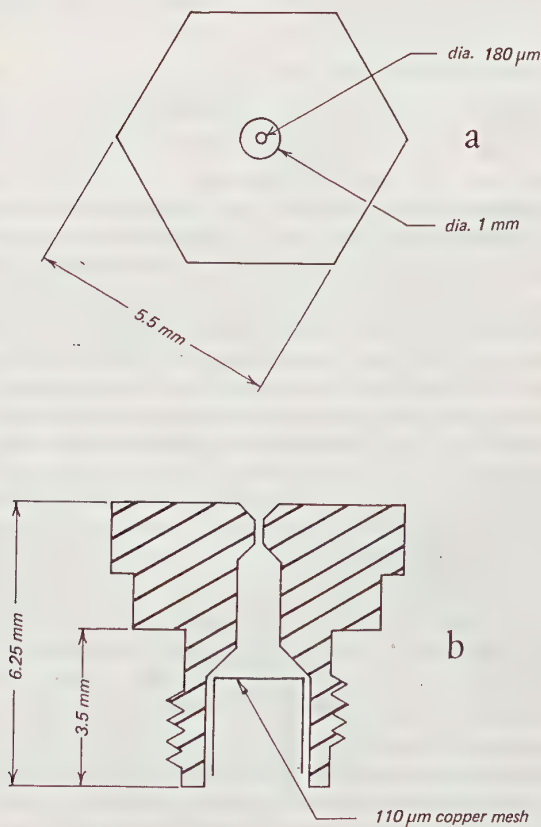


Figure 2: The nozzle and its dimensions: a) plan view; b) side view.

A 15 μ m filter (inline filter, Nupro, Ohio) is fitted to the top of the probe with a compression fitting. The probe is connected to the CO₂ cylinder with wire-reinforced plastic pressure tubing (CIG pressure tubing for CO₂ cylinders).

Two 1 m lengths of tubing are used with all joints (except that to the cylinder) sealed with teflon thread tape. The whole system must be pressure-tight otherwise leakage of CO₂ will occur resulting in a loss of pressure and thus loss of cooling effect at the nozzles. Both Carling (1981) and Walkotten (1976) recommend removal of the inline filter and flushing in reverse with gaseous CO₂ after 50 or so samples. If the nozzles become clogged at any stage, they should be removed and cleaned in acetone (and an ultrasonic bath). Provided the system is kept clean no problems should occur.

CO₂ is stored in aluminium cylinders (CIG VT size) which contain 10 kg of food grade CO₂. This amount of CO₂ discharges in about 15 minutes with six nozzles on the probe, i.e. at about 0.1 kg CO₂ per minute per nozzle. This is sufficient time to take two to three cores. Smaller cylinders (6 kg capacity) are also available and are easier to handle in the field.

Field Operation

The standpipes are hammered 30 cm into the streambed with a 15 kg post-driver. At some very consolidated sites this can take up to 5 minutes. Depth of penetration is measured with a graduated stick from a zero point marked on the post-driver; the distance of the zero point from the river bed before hammering equals the length of the stick. It is essential to drive the standpipes more or less vertically into the river bed. If driven in at too great an angle then the pipes will be bent during extraction, because a strong vertical force is exerted during extraction on the lifting assembly. The pipes are left in position for a day before freezing the core to allow the fauna to recover from disturbance caused by vibrations during the hammering. The top of the pipe should be capped and the holes where the steel pin is inserted should be plugged with rubber stoppers, if rain is expected, as no water must enter the standpipe before freezing.

To lessen the heating effect of water flow during freezing an open-ended galvanised iron cylinder (80 cm high, 40 cm diameter, 2 mm walls) is placed around the standpipe. Foam rubber attached to the lower edge of this cylinder helps to seal it to the river bed. Usually only a small current remains inside.

Freezing begins by inserting the probe in the standpipe, slowly opening the valve on the CO₂ cylinder and then upending the cylinder (onto a small table) to obtain liquid CO₂ from the nozzles. Timing of the operation begins when dry ice or "snow" issues from the top of the standpipe. To prevent the standpipe clogging with dry ice the probe should be jiggled occasionally throughout the freezing period. Satisfactory cores are usually frozen in 4 minutes, at which time ice builds up around the bottom of the standpipe where it enters the stream bed. Ambient water temperature is, naturally, an important factor governing freezing period. In the Thomson River, water temperatures during freezing varied from 11 to 18°C, but 4 minutes of freezing usually gave good cores over the whole of this range. With particularly consolidated sediments 6 minutes of freezing generally decreases the chance of the core breaking during extraction. At the end of the freezing period the CO₂ is turned off and the probe is removed.

Before the standpipe is extracted, the cylinder deflecting stream flow is removed, the lifting assembly (Fig. 1) is lowered over the standpipe, the two halves of the steel split sleeve are fitted underneath the lower welded ring and the steel pin (12 mm diameter) is inserted to secure the sleeves and lifting assembly to the standpipe. Two truck jacks (3.6 metric tonne lifting capacity) are then attached to the lifting chains and the apparatus is jacked vertically out of the

riverbed. With practice this whole operation (from the moment the CO₂ is turned off) can be completed in 2-3 minutes and should be done as quickly as possible particularly at warmer temperatures. Because there is a possibility of receiving cold burns during the freezing and extraction processes, leather gauntlets and a plastic visor (available from CIG) should be worn by at least one person. We have found that three people are usually required to operate this system efficiently, although that of Pugsley and Hynes (1983) could be operated by only one.

The frozen sediment is knocked off the standpipe with a brick bolster. The core is approximately 30 cm long and is removed in 10 cm sections; the junction between sections can be cut with an accuracy of ± 1 cm. The sections are sealed in pre-weighed plastic bags and transported to the laboratory in insulated boxes. No preservative is used, although the cores melt during the course of our field trips (about 5 days). No apparent decay of organic material occurs in this period. In the laboratory the sections are kept in a freezer until they are processed. On longer field trips it would probably be necessary to preserve the individual sections.

Laboratory Processing

Each section is weighed wet to the nearest gm in its pre-weighed plastic bag. (If preservatives are used, the sections of core should be weighed in the field before such additions are made.) Each section is then placed on a 150 μ m sieve and any fine mud and silt is washed through into a container. The fauna is separated from the remaining sediment by flotation in a concentrated solution of calcium chloride and stored in 70% ethanol. The sediment <150 μ m in grain size is made up to a known volume and a 10% subsample of the resultant slurry is taken. The subsample is dried at 100°C and weighed to enable the original weight of this sediment fraction to be calculated.

The coarser sediments are sieved wet through a series of sieves (150 μ m-64 mm). Sediment <2 mm in grain size is dried at 100°C before weighing; sediment >2 mm is weighed wet after pouring off excess water. All weighings are to the nearest gm. This is essential if the original weight or volume of water in each section of core (i.e. original wet weight minus dry weight of sediment) is to be estimated accurately. The slight overestimate resulting from weighing the coarser sediments while they are still wet possibly adds 0.5-1 gm to the total weight of sediment. This weight gain is comparable to the cumulative weight of the small amounts of sediment lost from many of the finer fractions during sieving. Thus no correction seems warranted given these limits to the accuracy of the procedure. The volume of the sediment fractions is estimated by displacement of water from a suitable container.

From the combined or total volume of water and sediment for each section of core the cross-sectional area is calculated, given that the length of each section is 10 cm. Estimating the cross-sectional area in this way is more accurate than estimating it from measurements of core circumference taken with a tape measure. The latter method gave areas that were up to approximately twice those computed from volumes, e.g. 114 cm² versus 51 cm², reflecting the uneven surface and non-circular circumference of most cores.

Results and Discussion

The dimensions and weights of some representative cores are given in Table 1. The river bed at site T16 was more consolidated than that at T6 and water temperatures at T16 (14-15°C) during coring were usually 2-3°C higher than those at T6. These factors probably account for the heavier cores from T6. The degree of variation, however, in either weight or volume is the same at both sites. Freezing for 6 minutes increases both volume and weight of the core by 20-30% at these two sites. Pugsley and Hynes (1983) froze their cores for 20 minutes with liquid nitrogen (which is colder than liquid CO₂) and obtained cores of 10 cm diameter at water temperatures >20°C and cores of 15 cm diameter in the winter (probably 0-4°C in Ontario, Canada). Carling (1981) obtained cores in 10-15 minutes with diameters of 14-27 cm using liquid CO₂ in moorland streams in the Pennines (U.K.); these cores were about 30 cm long and weighed 5-15 kg. Carling gives no details of ambient water temperatures, but these were probably lower than we encountered.

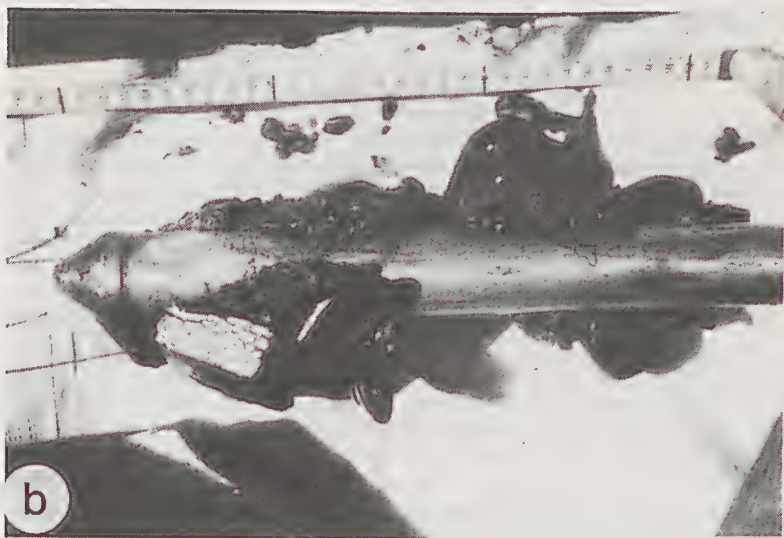
Table 1: Data from representative cores taken at two sites on the Thomson River. The cores were 30 cm long and were frozen for 4 minutes.

	T16	T6
Number of cores	11	9
Range of core wet weights (kg)	1.6-4.7	2.9-6.3
Mean wet weight (kg)	3.2	4.1
Coefficient of variation of wet weight (%)	28.3	28.0
Range of core volumes (ml)	680-1930	1240-2640
Mean volume (ml)	1340	1760
Coefficient of variation of volume (%)	27.3	27.1
Mean diameter of core (cm)	9	10

The cores are more or less cylindrical throughout their length (Fig. 3), but, naturally, the surfaces are uneven, particularly where large rocks are exposed: individual rocks up to 9.8 kg were extracted. Sometimes cores break during extraction; the damage is usually obvious (Fig. 3). Problems may occur in freezing the loose surface layers of the stream bed: generally only the consolidated sediment will be frozen and loose rocks not embedded in the matrix will not normally be retrieved. Pugsley and Hynes (1983) removed any loose rocks before freezing their cores. Such loose rocks undoubtedly have attached fauna and thus the density of invertebrates in the uppermost (0-10 cm) section of the core will be somewhat underestimated. Surber samples taken (to a depth of 10 cm) at the same time as cores gave higher faunal densities for this uppermost layer. A full discussion of this difference and comparison of faunal densities with those found in other studies will be given elsewhere.



a



b

Figure 3: a) A typical core from T6. The uneven surface is clearly seen. b) A broken core from T16. Most of one side of the core is missing. In both photographs the scales are in cm.

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A SUBSAMPLER FOR SAMPLES OF BENTHIC INVERTEBRATES

by

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Abstract

A subsampler for use with samples of benthic invertebrates is described. The distribution of animals within the subsampler is random thus ensuring reliable estimates of total numbers.

Introduction

A considerable saving in time can be made when sorting benthic invertebrates by using subsamples to estimate the total numbers in a sample. A number of subsamplers for dealing with benthic material have been described (Waters, 1969; Hickley, 1975; Wrona *et al.*, 1982) but for various reasons none of these were suitable: either they were too complex to build or required compressed air to operate. Several simple subsamplers have also been described (Klattenberg, 1975; Södergren, 1974), but it is not clear how reliable they are in estimating total numbers. The following note describes a subsampler that has been used for a number of years in the Biological Survey (now Environmental Records) laboratory of the Museum of Victoria. This device is operated by hand and requires only a supply of water.

Construction and Use

The subsampler consists of an inner square box which sits in an outer watertight box (Fig. 1). The inner dimensions of the outer box are 365 x 365 x 147 (high) mm; the walls (and bottom) are 6 mm thick. The external dimensions of the inner box are 362 x 362 x 147 mm, and the walls are 4.5 mm thick. The bottom of the inner box consists of 150 μ m nylon mesh and has been divided into 100 squares or cells, each square being 35 x 35 mm; the walls of each square are 1.5 mm thick and 29 mm high. The subsampler is made entirely of PVC sheets. The joints of the outer box are braced with strips of angled PVC.

A lid (Fig. 1) is needed to make the outer box watertight. The lid, a square (380 x 380 x 6 mm thick) sheet of PVC, is clamped to the outer box by means of 12 clips, 3 on each side. To ensure a watertight fit strips of neoprene rubber (18 mm wide, 8 mm thick) are stuck to the underside of the lid along all four margins. When the lid is clamped down the strips of rubber seal the lid to the upper edges of both the outer and inner boxes.

Before the sample is placed in the subsampler the organic fraction is separated from the inorganic material (by flotation using a saturated solution of calcium chloride). Large animals in the organic fraction (if they occur) are then removed and can be added to the estimate of total numbers. Finally, the organic fraction is emptied into the inner box after this box has been placed in the outer box. Enough water is then added to ensure a depth of about 3-4 cm above the walls of the cells which divide the bottom. The lid is clamped down and the box rocked vigorously in each of the four directions at right angles to the sides of the

box. The inner box is then removed (after ensuring no animals are stuck to the lid) and placed (in a sink for instance) in about 1 cm of water. Thus the contents of each cell will be submerged but isolated from each other because each cell is 2.9 cm high. The contents can be removed with a pipette and tweezers but a vacuum pump is more efficient and less tiring. This pump consists of an Erlenmyer flask connected by hose to a water jet pump attached to a tap. A second hose from the flask is used to suck the contents of each cell into the flask. An electrical vacuum pump could be used instead of the water jet pump.

In this laboratory a 10% subsample, i.e. 10 cells, is usually taken. The cells are selected at random using pairs of random numbers to provide the co-ordinates in the inner box of the selected cell. The contents of the remaining 90 cells can be removed by flushing with water after up-ending the inner box. With practice the whole operation from placing the sample in the inner box to flushing out the remaining 90% takes about 10 minutes, provided a vacuum pump is used to suck out the contents of the ten selected cells. The whole operation takes about twice as long if tweezers and pipettes are used.

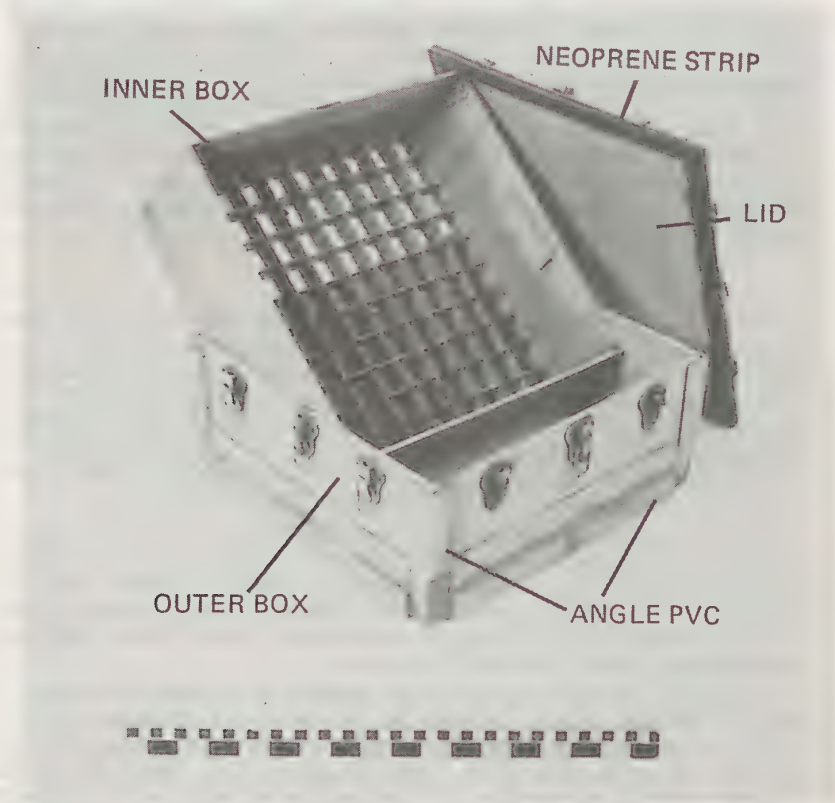


Figure 1. A view of the dismantled subsampler. The scale is in cm and inches.

Statistical Considerations

In order to obtain reliable estimates of the total number of invertebrates in a sample it is necessary to demonstrate that the animals are at least randomly distributed within the subsampler. Elliott (1977) outlines a suitable statistical test based on an approximation to the chi-squared distribution which determines whether a given set of counts conforms to a Poisson series; agreement with this series is an accepted test for randomness. In more than 500 tests with this subsampler, in which the total specimens in each of the 10 cells in a subsample were counted, only one instance of non-random distribution was found. In this case the animals showed a clumped distribution, but the chi-squared value ($\chi^2 = 20.4$) was just above the upper boundary of the chi-squared limits for randomness ($\chi^2 = 19.0$; degrees of freedom = 9). On the other hand, there were 17 cases where the chi-squared value was less than 2.7 (the lower boundary) and which thus displayed an even distribution. In fact, in 60% of all cases the variance was less than the mean, but not sufficiently so to result in an even distribution when tested with the chi-squared statistic. In one trial in which the whole sample was counted the total count for each set of ten cells varied from 35 to 49, but all except two were between 35 and 43; the total number of individuals was 399. Individual taxa also showed random distribution within the subsampler (Table 1): in no case did the chi-squared values fall outside the appropriate limits.

Table 1. Some statistics from subsampling various benthic invertebrate taxa. The range of values is derived from five representative samples of each taxon; ten cells were counted for each sample. The chi-squared values are calculated after Elliott (1977) for nine degrees of freedom.

	Range of mean numbers per cell	Range of standard deviations	Range of chi-squared values
Chironomidae	3.5-20.7	1.6-4.1	7.0-12.6
Leptophlebiidae	1.8-7.5	1.2-3.6	7.6-15.8
Leptoceridae	1.1-5.1	0.7-2.4	4.5-17.8
Oligochaeta	3.5-14.2	1.7-2.7	3.4-15.6

With animals distributed randomly in the subsampler the precision of the estimate of total numbers depends only on the number of animals counted. Thus if 100 are counted the standard error of the estimate of the total is $\pm 10\%$; if 400 are counted the standard error is $\pm 5\%$ (see Elliott, 1977). A suitable level of precision is not easy to set, however, if different taxa with different levels of abundance are encountered in a sample. One hundred individuals of each taxon could be counted, but for the rarer taxa this procedure could well require the examination of the whole sample, thus defeating the purpose of subsampling. If the aim of the study is the detection of differences in community composition, then the rarer taxa generally contribute little or nothing to such patterns, and are usually ignored in any analysis (Gauch, 1982). Wrona et al. (1982) also discuss these problems and conclude that major-trends in community composition can reliably be detected using a standard number of subsamples, as done here.

Finally, it should be remembered that the variability in total abundance of individuals from a set of samples at one site is often large, e.g. the estimates of density of the benthos from the La Trobe River had 95% confidence limits of up to $\pm 50\%$ (Marchant et al., 1984). Any additional error from subsampling individual samples, e.g. a standard error of 10%, contributes only a small amount

to the total level of error. In this case 95% confidence limits of 50% approximately equal a standard error of 25%. Summing the squares of the two standard errors ($25^2 + 10^2$) and taking the square root as outlined by Gauch (1982) gives a total standard error of approximately 27% or confidence limits of 54%. This is a negligible increase in error for a great saving in time.

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